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THERMAL ANALYSIS OF SHELL AND TUBE TYPE HEAT EXCHANGER TO DEMONSTRATE THE HEAT TRANSFER CAPABILITIES OF VARIOUS THERMAL MATERIALS USING ANSYS

Nakka Sita Rama Raju
AMIE, Institution of Engineers, India

V Jaya Prasad
Assistant Professor, UCEK, JNTUK Kakinada, Andhra Pradesh, India

S Kamaluddin
Professor, Chirala Engineering College, Andhra Pradesh, India

A Sunny Kumar
Assistant Professor, GITAM University, Visakhapatnam, Andhra Pradesh, India

ABSTRACT

This paper consists of a simplified model of shell and tube type heat exchanger having both interacting mediums as water and steam. In this paper we have first designed a shell and tube heat exchanger to heat water from 40℃ to 70℃ by steam at 140℃ temperature. The design has been done using Kern's method in order to obtain various dimensions such as shell, tubes, baffles etc. A computer model using CATIA V5 has been developed by using the derived dimensions of heat exchanger. Then the thermal simulation in ANSYS has been performed by applying several thermal loads on different faces and edges. The heat transfer capabilities of several thermal materials have been compared by assigning different materials.

Key words: Shell and tube type heat exchanger, Kern's method, Ansys 14.5, Thermal analysis, Thermal materials.

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1. INTRODUCTION

Heat exchanger is a mechanical device which is used for the purpose of exchange of heats between two fluids at different temperatures. Most widely used in various fields such as oil refineries, thermal power plants, chemical industries and many more. This high degree of acceptance is due to the comparatively large ratio of heat transfer area to volume & weight, easy cleaning methods, easily

replaceable parts etc. There are various types of heat exchangers available in the industry, however the Shell and Tube Type heat exchanger is probably the most used and widespread type of the heat exchanger's classification. Shell and tube type heat exchanger consists of a number of tubes through which one fluid flows. Another fluid flows through the shell which encloses the tubes and other supporting items like baffles, tube header sheets, gaskets etc. The heat exchange between the two fluids takes place through the wall of the tubes.

An attempt is made in this paper for the Design of shell and tube type heat exchanger by modeling in CATIA V5[4] by taking the Inner diameter of shell as 300 mm, Outer diameter of tube as25.4mm, length of tube as 1500mm and by using modeling procedure. Assembly of Shell and tube with water and steam as mediums are done. By using ANSYS software, the thermal analysis of Shell and Tube heat exchanger [5] is carried out by varying the shell & tube materials. With the help of the available numerical results, the design of Shell and Tube type heat exchangers can be altered for better efficiency.

The Tubular heat exchangers are generally built using circular tubes, elliptical, rectangular or round/flat twisted tubes based on applications. Tubular exchangers can be designed for high pressures relative to environment and high pressure differences between the fluids.

2. THEORITICAL ANALYSIS

Shell and tube type heat exchangers are designed normally by using Kern's method [2]. Kern's method [2][6] is mostly used for the preliminary design. In this paper we have designed a simple shell and tube type heat exchanger to heat water from 40°C to 70°C by using steam at 140°C temperature by using Kern's method [2]. The steps of designing are described as follows:

a) First we consider the energy balance to find out the values of some unknown temperature values. Certainly some inputs like hot fluid inlet and outlet temperatures, cold fluid inlet temperature, and mass flow rates of the two fluids are needed to serve the purpose. The energy balance equation may be given as:

$Q = m\text{h}\ \text{Cph}\ (th1\text{-}th2) = mcC\text{c}\ (\text{t}c2\text{-}tc1)$[1]

b) Then we consider the LMTD expression to find its Value:

LMTD = $(\Delta T1-\Delta T2)$ / In $(\Delta T1/\Delta T2)$

Where, $\Delta T1 = th1\text{-}tc2$ and $\Delta T2 = th2\text{-}tc1$.

c) Our next step is to calculate the area required of the heat exchanger (on the basis of assumed U0), number of tubes, tube bundle diameter, diameter of shell and its thickness with the help of following expressions:

$A = Q / (Uo\Delta T)$

$Nt = A / (\pi dtol)$

$Db = dto\ (Nt / K1)1/n1$

Di = Db + additional clearance

Do = Di + 2 × thickness

d) Then we calculate the proper baffle dimension viz. its diameter, thickness and baffle spacing[3].

e) Our next step is to find out heat transfer coefficients on the inner and outer surface of the tubes using following correlation:

$1/U = (1/Ui) + (/Uo)$

f) Then by the values obtained by the above equation we calculate the actual value of heat transfer coefficient and check whether the actual value is greater than the assumed one or not.

g) After rigorous mathematical calculations we have found out following values of interest:

mh	=	268 kg/sec
mc	=	334 kg/sec
$th1$	=	140°C
$th2$	=	98°C
$tc1$	=	40°C
$tc2$	=	70°C.
A	=	4.30$mm2$
Dto	=	25.4 mm
Dti	=	21.18 mm
Nt	=	36
Di	=	330 mm
Do	=	350 mm
Number of baffles	=	10
Diameter of baffles	=	296 mm

B= 130 mm

All baffles 25% cut in order to assure the shell side flow.

3. SOLUTION METHOD

In this paper we have proposed a software model of shell and tube type heat exchanger exactly of the above derived dimensions. After generating the model we have run the heat exchanger thermal simulation. The results obtained were quite familiar with general considerations about the hierarchical nature of thermal conductivities of the concerned materials. ANSYS 14.5[5][7] has been used for the purpose of model generation and its further analysis. The solution phase generally involves three major steps which are described in detail under next sub headings:

3.1. Making of Software Model

Using the above derived dimensions of shell, tubes and baffles we have made a software model using ANSYS 14.5 [5]. The parts individually as well as in assembly are as shown below

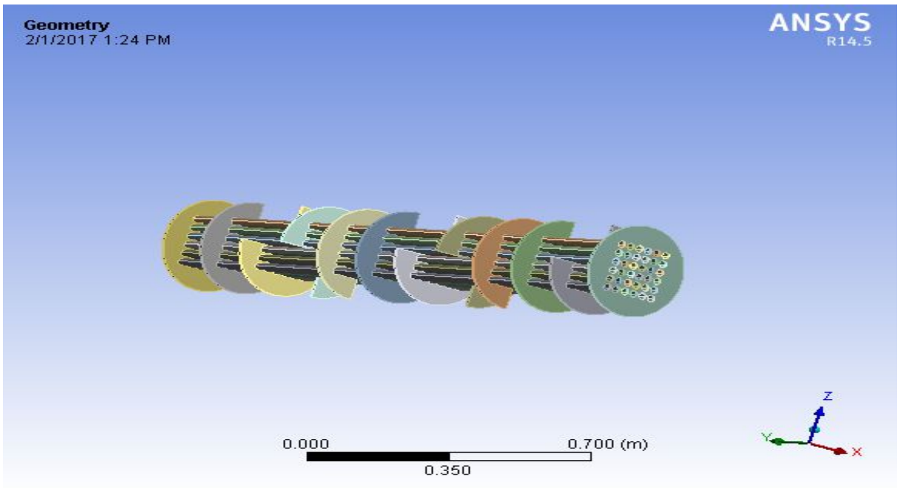


Figure 1 Arrangements of tubes and baffles

3.2. Mesh Generation

The mesh has been generated to perform finite element analysis. In generating the mesh a compromise between computer speed and mesh quality has been adopted. The generated mesh along with its information has been shown in the following figure:

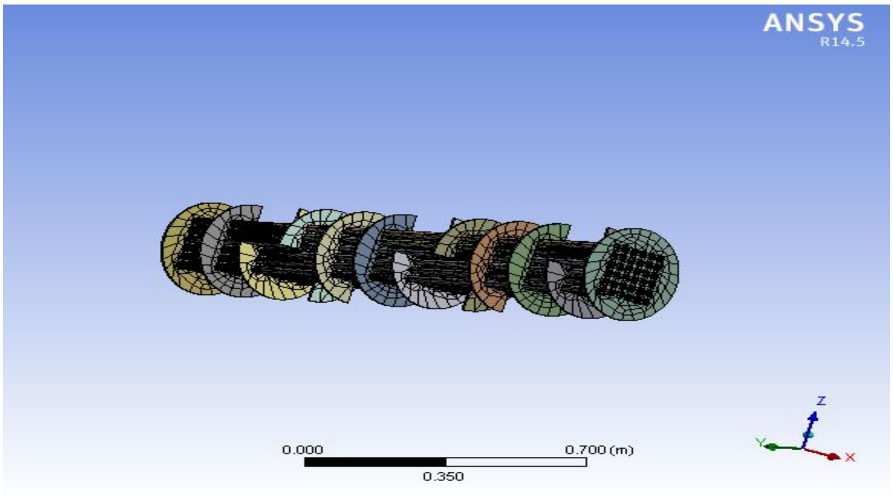


Figure 2 Meshing

4. RESULTS AND DISCUSSIONS

Here we have employed four combinations of materials and the heat flux obtained from them is as described below:

Figure3 shows the total heat flux when we have assigned SS 304 as the material of the heat exchanger. Corrosion resistance of material is essential in heat transfer applications where fluids are involved. Stainless steel is containing 18 to 20 % chromium content and making it superior corrosion resistant. The thermal conductivity of SS 304 is 16 W/m-K and with SS 304 the maximum value of heat flux obtained is 14335 w/ m^2 while the minimum value is 0.8 w/ m^2.

Figure4 is showing total heat flux when Steel 1008 is assigned as the material. Steel 1008 has a thermal conductivity of 36 W/m-K and with Steel 1008 the maximum value of total heat flux obtained is 16573 w/ m^2 while the minimum value is 0.184 w/ m^2. Steel 1008 is not superior at corrosion resistance as it is not having any Chromium content in the material composition. But the thermal conductivity of Steel 1008 is two times the thermal conductivity of SS 304. The heat transfer properties of materials used in the construction of heat exchangers cannot be based exclusively on the corrosion resistance itself. The heat transfer depends on thermal conductivity also.

Figure5 is showing the total heat flux content when Copper is assigned as the material. Copper is excellent at corrosion resistance. The thermal conductivity of copper is 400 W/m-K and with this, the maximum total heat flux obtained is 1.45 x 10^5 w/ m2 while the minimum value is 4.0 w/ m2. The thermal conductivity of copper is almost 25times to the SS 304 and 12 times to the Steel 1008.

Figure6 is showing the total heat flux obtained when combination of Steel 1008 and copper assigned. With this combination of Steel 1008 and Copper the maximum total heat flux obtained is 20259 w/ m^2 while the minimum value is 0.7 w/ m^2. Here in Figure6 we tried to get advantages of both the properties of Steel 1008 and copper. The only affordable material that has similar corrosion resistance to copper is stainless steel. However, the thermal conductivity of stainless steel is 1/25th that of copper.

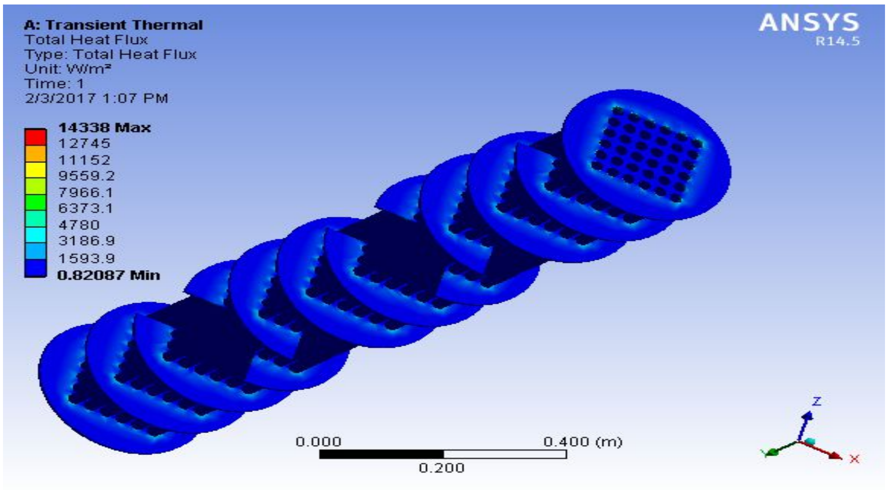


Figure 3 Heat flux in heat exchanger when SS 304 is assigned.

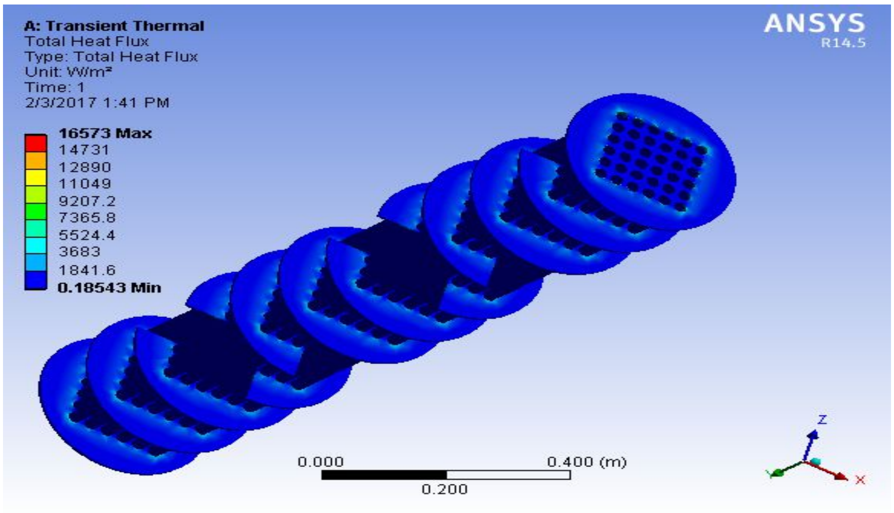


Figure 4 Total heat flux when Steel 1008 is assigned

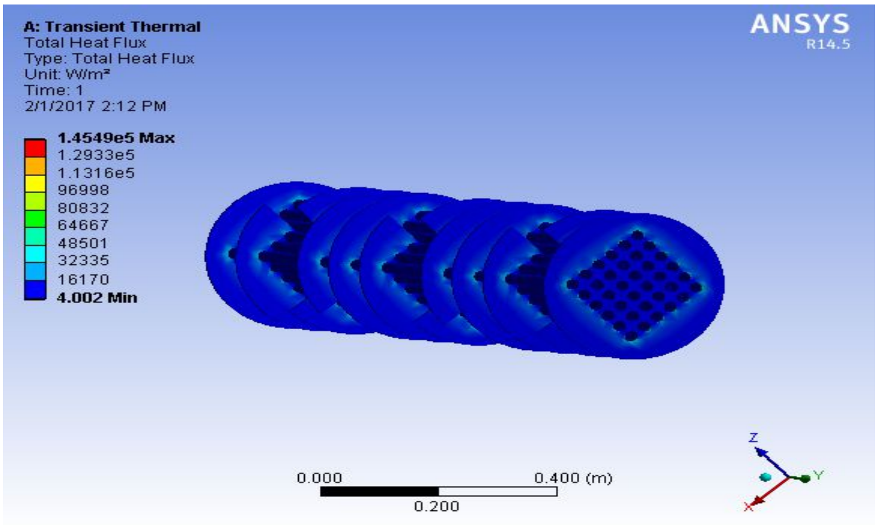


Figure 5 Total heat flux when copper is assigned

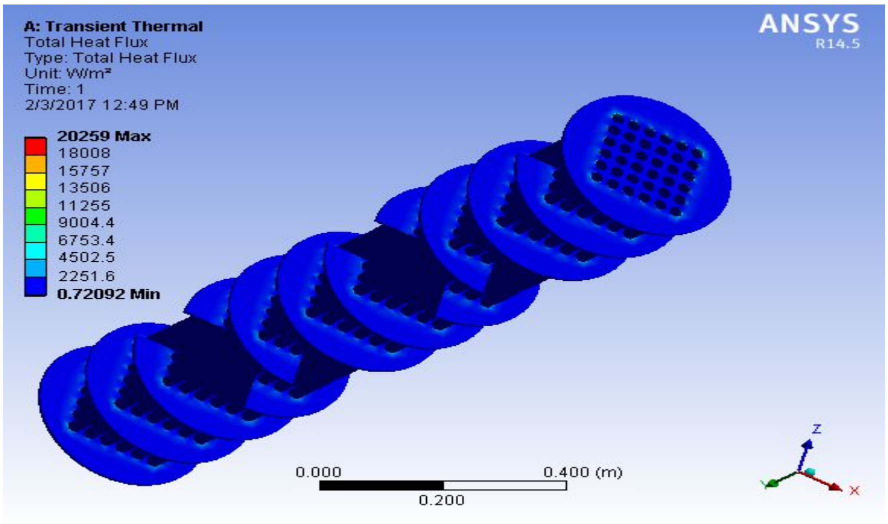
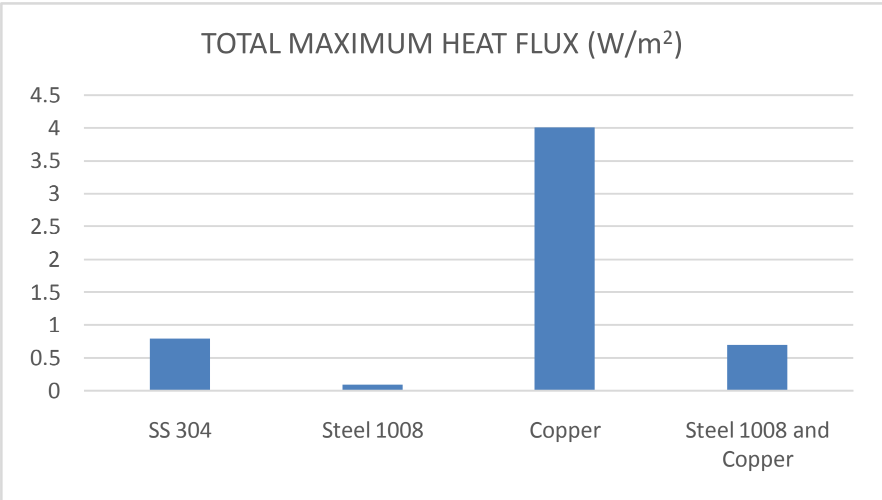
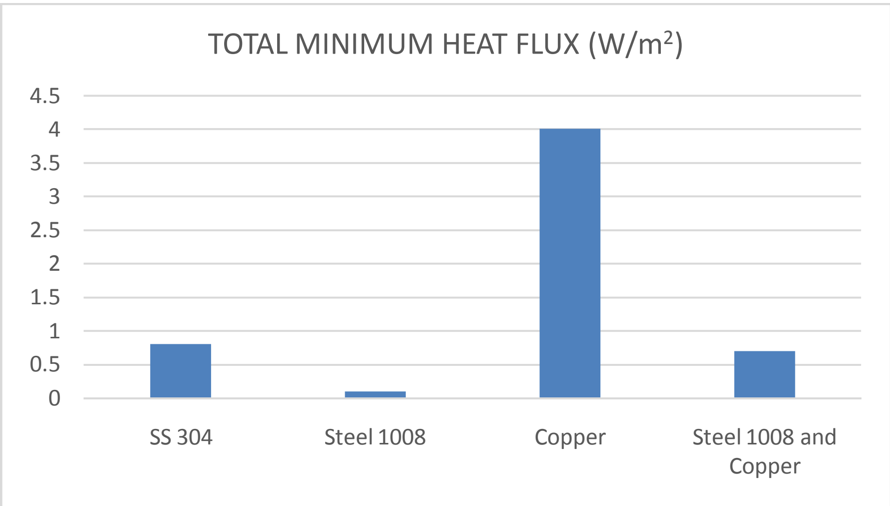


Figure 6 Combination of Steel 1008 shell and Copper tubes & baffles is assigned

The results of the above study when assigned different thermal materials to the heat exchangers are shown in graphs. X-axis showing different materials assigned and the Y-axis showing heat flux in W/m^2.





5. CONCLUSION

From this study it is clear that if we assign copper to the whole assembly then we shall get the best possible value of heat flux amongst the discussed materials; however that will also be a very costly affair. Secondly the outer surface of shell is generally insulated so that it may be assumed that no heat transfer is taking place in between shell and surroundings. Hence it will be a good deal to assign combination of Steel 1008 and Copper as heat exchanger material. Steel is also a moderate conductor of heat and can be employed, in case greater material economy and corrosion resistance is desired.

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